

SAFE INTELLIGENCE

Reliability and intelligence in predictive / smart maintenance for mobile machines

by using edge cloud, flexible distributed software architectures and reliable machine learning

Agenda

1. Fraunhofer ESK / IKS

2. Maintenance

- Evolution in maintenance
- Our research for smart maintenance
- Project INVIA
 - Edge computing
 - Distributed Software Architecture
 - Assuring Artificial Intelligence for prediction
 - Field trials / prototype

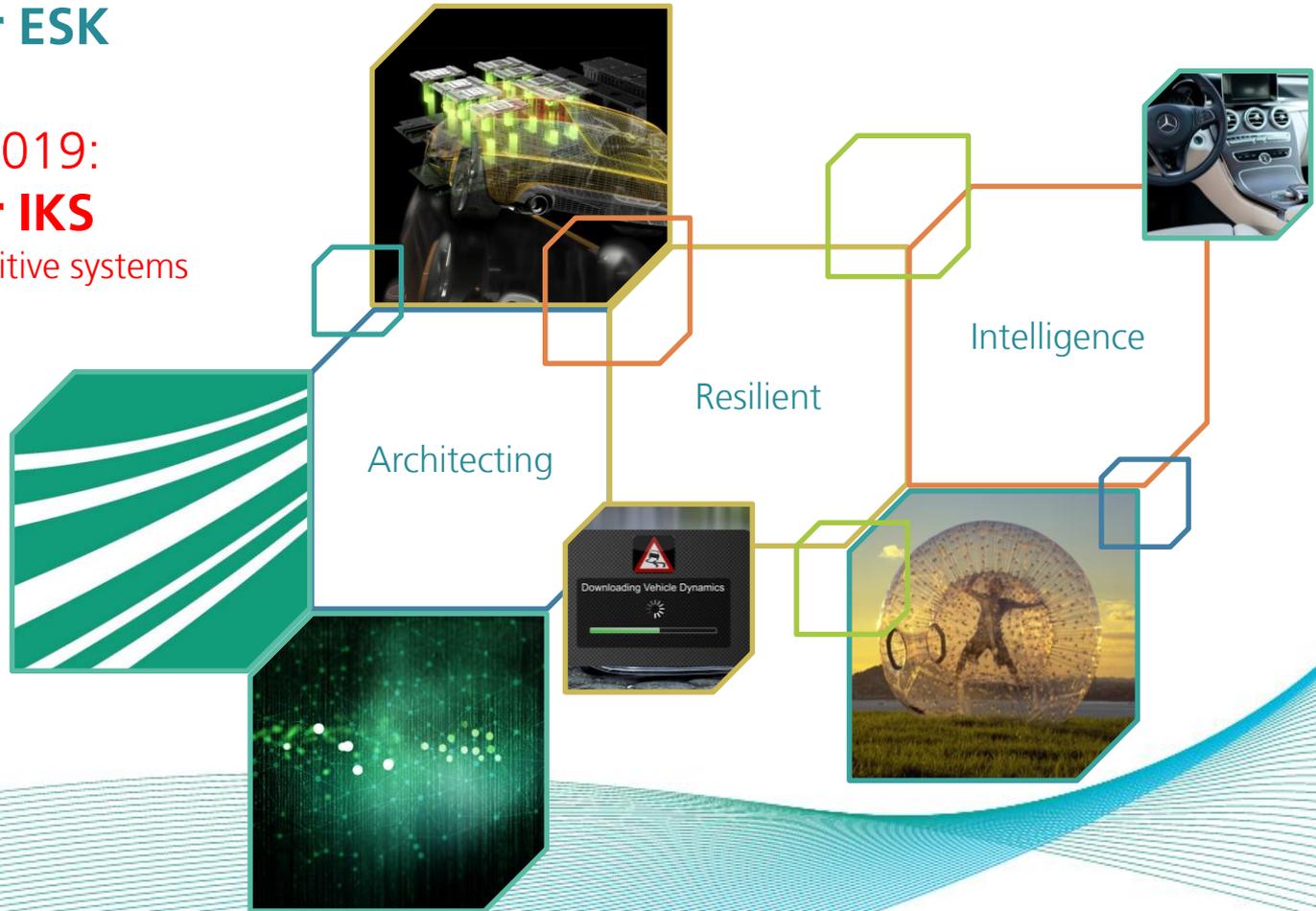
3. Summary / future topics

Fraunhofer ESK

December 2019:

Fraunhofer IKS

Institute for cognitive systems



Our Focus on Cognitive Systems



Cognitive Behavior: Architectures safeguarding untrustworthy AI and methods for assurance AI-based functionality



Cognitive Architectures: adaptive, adaptable and distributed architectures enabling »Software-Defined Systems«



Cognitive Connectedness: networked functionality and systems acting as intelligent collectives



Our Scientific Competences to address these aspects

Resilient Artificial Intelligence
Robust, explainable, transparent AI
for resource-limited systems



Adaptable and Adaptive Architectures
Using most modern software technologies for safety-critical
and highly-reliable technical systems



Safety, Reliability, Availability
Assuring safety, reliability, and availability in spite of and
because of using modern software technology



Evolution in Maintenance

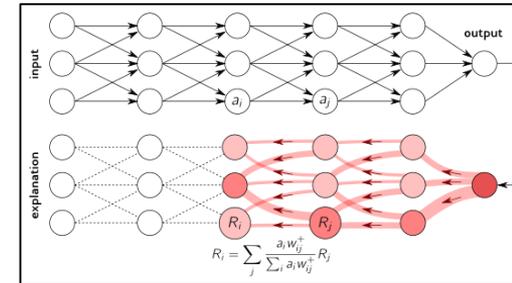
- History

- Corrective maintenance → Preventive maintenance → Risk based maintenance



- Predictive Maintenance

- Research started in 2001
- Based on condition monitoring and evaluation, model based or AI based
- well introduced, many installations in different domains
- Extension: Combination with effects of potentially defective components on the overall system and corresponding maintenance



- Prescriptive Maintenance

- Current research topic + first implementations
- Vision: Machine is able to solve problems itself or is able to lengthen machine availability (self acting → self adaptive)



Evolution in Maintenance

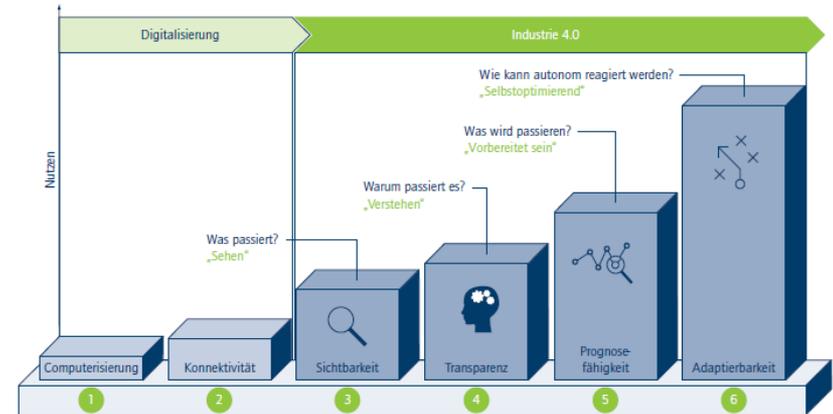
- Assistance Systems

- Connected mobile devices (→ Augmented Reality AR)
- Cooperation between machine and human (HMC)
- Complete Integration in predictive / prescriptive maintenance



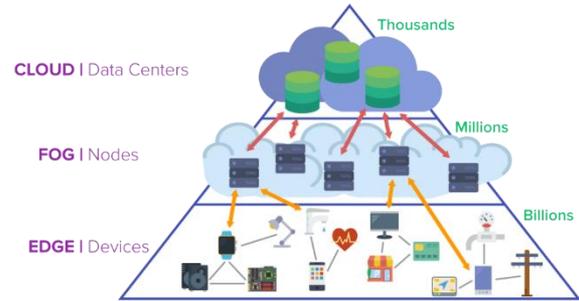
- Smart Maintenance

Smart Maintenance refers to a learning-oriented, self-regulated, intelligent maintenance with the aim of maximizing the technical and economic effectiveness of maintenance, taking into account the existing production system through the use of digital applications. " (Smart Maintenance , Acatech Study, Okt. 2019)



Our research for smart maintenance

- **FOG/ EDGE / Cloud Computing**
 - machine gateway
 - Mobile Edge computing
 - Cognitive Connectedness
- **Flexible Software Architecture**
 - virtualisation → container based
 - Service oriented approach (industrial SOA)
- **Reliability in AI based prediction solutions**
 - „explainable AI“
 - mechanisms to avoid wrong decisions



Project INVIA – resource adaptive mobile assistant system for complex agricultural machines

Goal

Research, conception and prototype implementation of a new Mobile Edge Computing / Cloud-based assistance system for maintenance (diagnostics, training) of complex agricultural machinery “

Partners

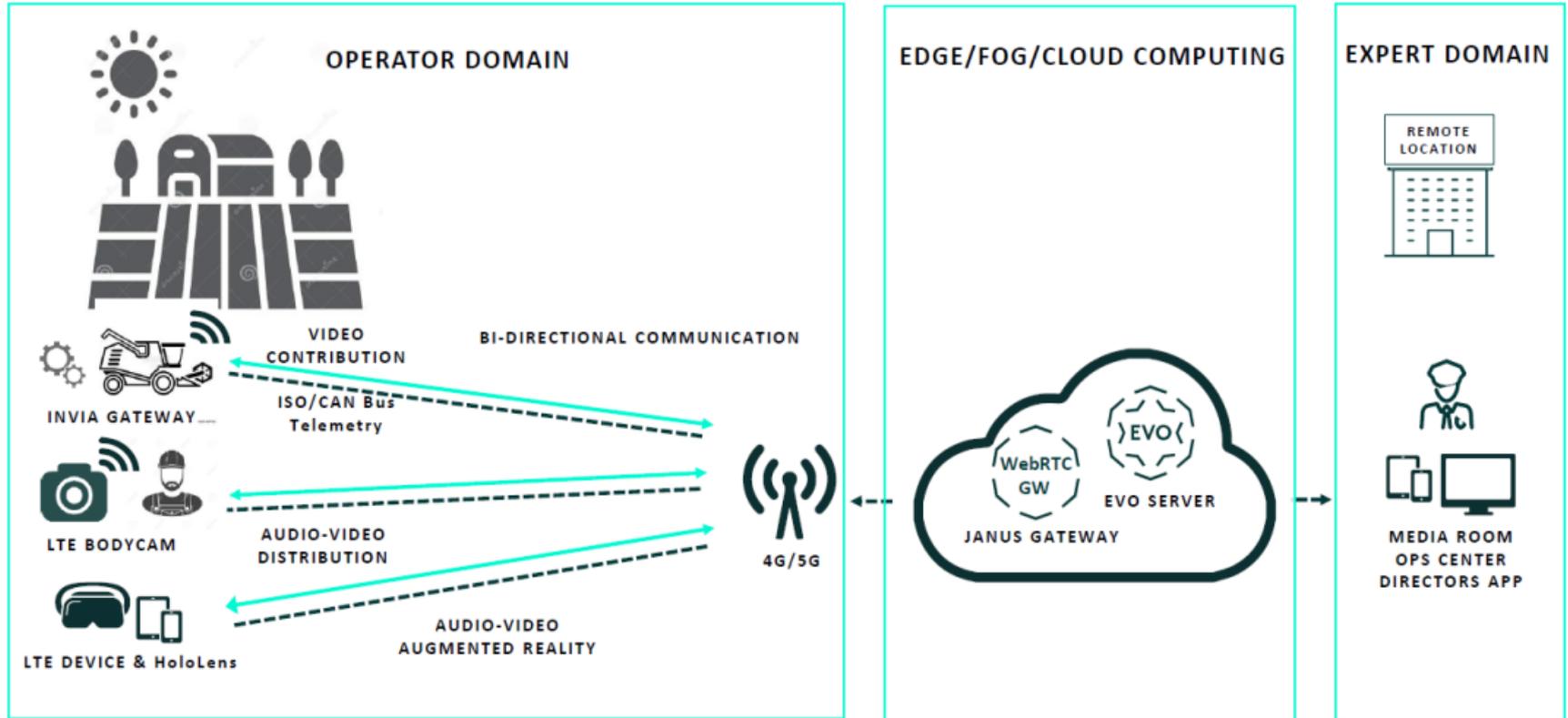


Project INVIA / main goals

- **Real-time video-based interactive remote assistance for maintenance**
- **Adaptivity of the system**
 - Adaptation dependent on variable quality of communication networks
 - Integration of different mobile devices
- **Use cases with two different machine concepts**
 - Self-propelled beet harvester (Holmer)
 - Drawn single grain sowing machine (Horsch)



Scenario Smart Maintenance



EDGE Computing

- Definition
 - Edge computing, in contrast to cloud computing, refers to the decentralized data processing at the edge of the network
 - Edge computing can be the computing power in a machine gateway or in a cellular base station (MEC)
- Processing information close to the machine
- Tasks of the machine gateways in INVIA
 - Gateway between machine and mobile edge cloud (MEC)
 - Bundles data streams from machine (CAN, cameras, terminal)
 - Integration of (AR-) data glasses, tablet, smartphone of the service technician on site
 - Flexible service provisioning



Distributed software architecture

- **Standard architecture:**

- fixed allocation of software at the place where the function is needed

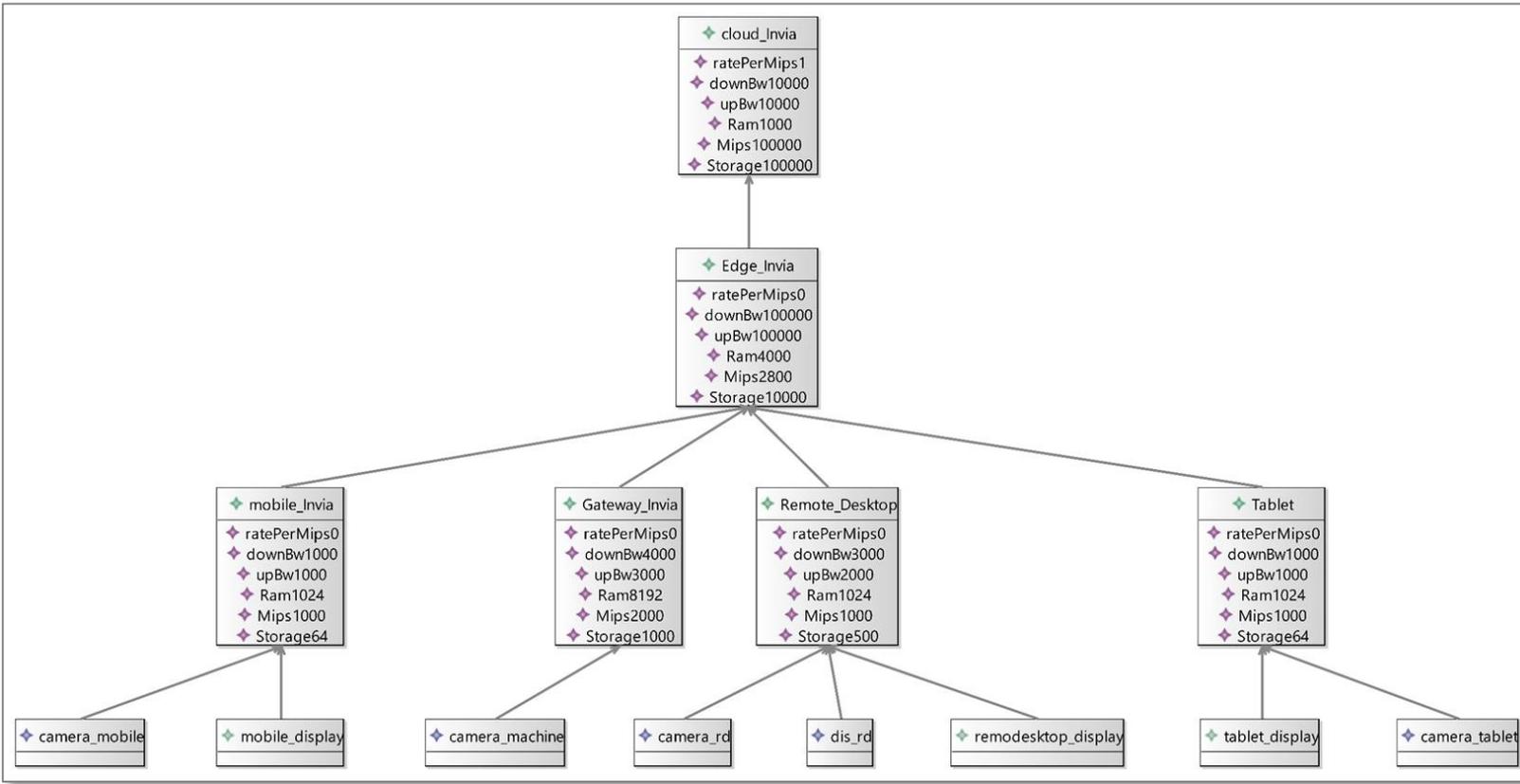
- **Flexible architecture:**

- If conditions (connectivity, resources, ..) change, software should be able to "wander" or at least be able to respond to it, e.g. adaptive bandwidth usage

→ To provide a **highly reliable** application, software / services must either be optimally distributed statically or be dynamically placeable.

→ Optimal Distribution can be done **only with suitable simulation**

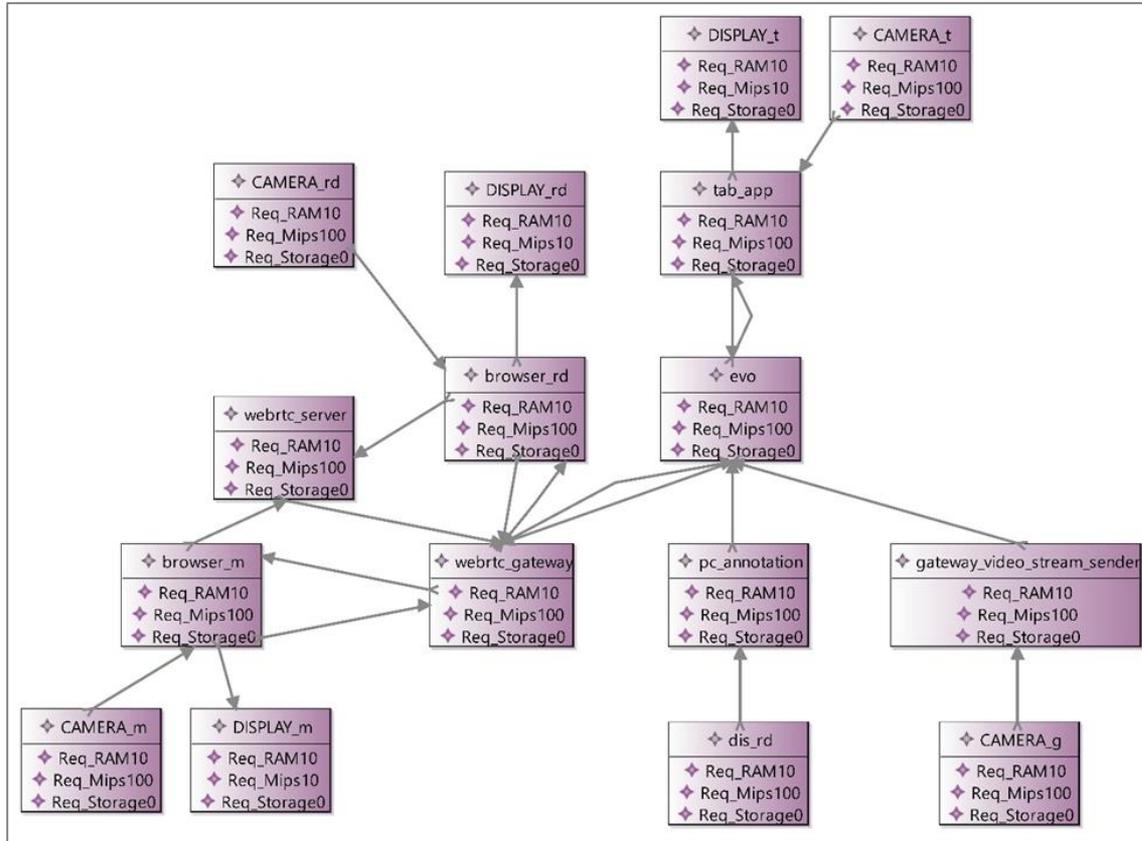
Hardware Simulation Model



Hardware Properties:

- CPU Speed
- Min/Max
- Bandwidth
- RAM
- Storage Size
- Connections

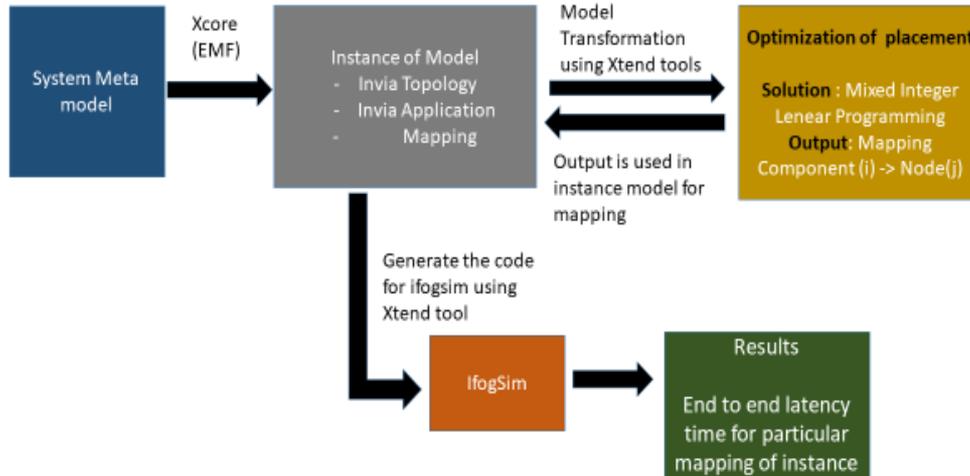
Software Simulation Model



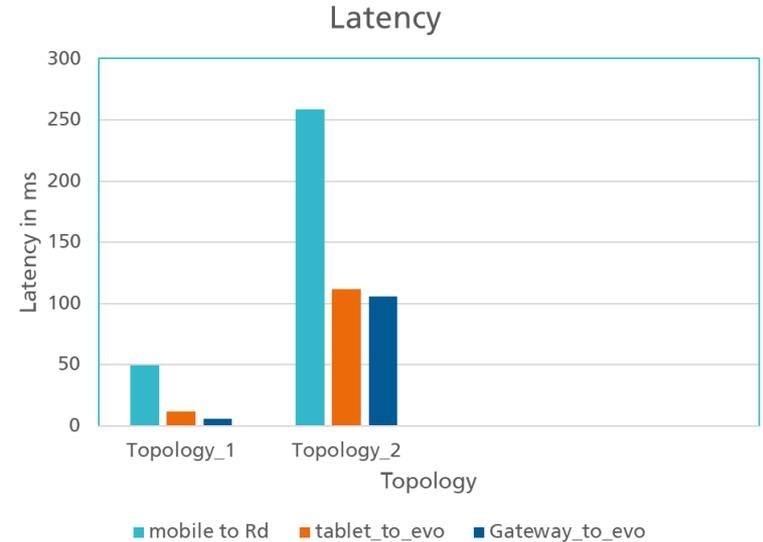
Software Requirements:

- RAM
- CPU
- Storage Size
- Dependencies

Simulation Toolchain for Smart Maintenance Software Architecture



simulation-
environment



simulation results

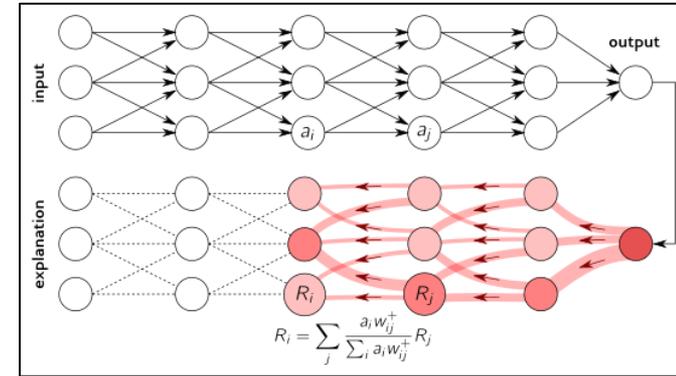
(1) Assuring Artificial Intelligence for prediction

Assurable AI, by improving

- **Explainability:** Traceability of how the algorithm came to a concrete result (for one specific case)
- **Transparency:** the algorithms behavior is reproducible, in general (for any thinkable case)
- **Robustness:** small modifications of the algorithm's input lead to only a small impact on its output

Current status of assuring AI-based algorithms

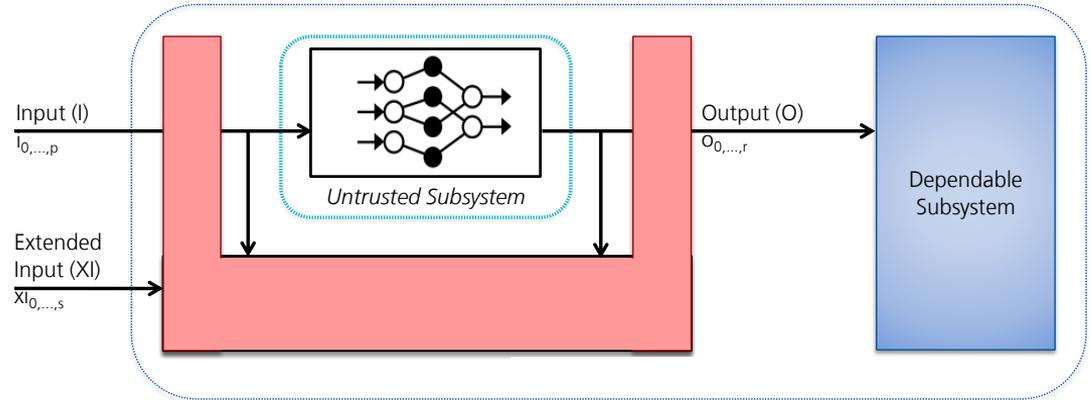
- very first steps, e.g. using **saliency maps** by Layer-wise Relevance Propagation (LRP)
- AI should be considered as **untrustworthy** from a resilience point of view



(2) Assuring Artificial Intelligence for prediction

Our approach

- We cannot trust AI
 - Reliability-Envelope / -Bag
 - Separate Reliability-Path
 - X-Validation



- However, **the more reliable information** we get on AI's performance and uncertainty, **the better**



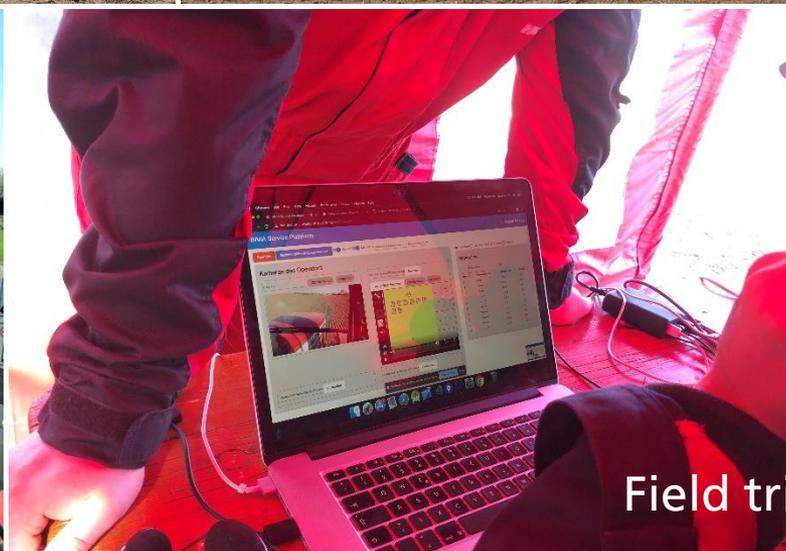
Field trial oct 2018



Field trial oct. 2018



Field trial april 2019



Field trial april 2019

Summary / Future of Maintenance

- **Current Research: predictive → prescriptive maintenance**
- **Reliability of distributed software can be optimized by simulation**
- **There exist already some mechanisms to make AI more reliable**
- **Future topics:**
 - Adaptive machine safety for maintenance during operation
 - Usage of mobile maintenance robots

SAFE INTELLIGENCE

THANK YOU FOR YOUR TIME AND ATTENTION!

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